# An integrated policy framework for rural off-grid electrification programs[1]

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**Abstract**

Rural electrification programs have a long history of failure, mostly associated to the lack of long-term support and sustainability of the projects. In this paper we propose a new policy framework for rural electrification programs that tries to address the major shortcomings of the existing ones regarding their sustainability, and we illustrate it with an application to Guatemala, in which this new framework was proposed.

*Keywords: Off-grid electrification, policy framework, Central America*

*JEL Codes: E61, G38, O21, Q01, Q48*

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# 1. Introduction

One of the greatest energy challenges in the world is the provision of electricity to the more than 1.5 billion people worldwide who do not have access to it. The United Nations (2005) has already stated how this access is key for achieving the Millennium Development Goals, and, in general terms, for economic and social development.

Most of the population without access to electricity lives in rural areas, where electrification rates are around 58%, compared to 90% in urban areas. In these areas, people are largely dependent on traditional biomass for fulfilling their energy needs (World Energy Council 1999), which creates additional environmental problems and further limits their development prospects.

However, and in spite of the pressing need that this situation creates, the future is not bright. The IEA (2008) estimates that, in absence of vigorous policies, in 2030 1.3 billion people in the world will still live without access to electricity.

There are several reasons for this pessimistic forecast. Firstly, remote rural areas in developing countries are usually very poor and their energy consumption per capita is (as a cause and as a consequence) very low. In addition, households tend to be dispersed over remote and inaccessible areas. Combined with low consumption levels, this results in very high electrification costs. In turn, this makes off-grid rural electrification activities (network expansion and operation, as well as possible investments in new generation capacity) very unattractive for private investors.

This has made many governments to step in and promote rural electrification programs. Together with the fact that, in many countries, access to electricity is

a constitutional right, the government is the subsidiary authority responsible for rural electrification. Unfortunately, the results have not been very positive. On the one hand, investment levels have remained low, only around 30% of the required effort. On the other hand, many analyses of electrification programs have concluded that many programs were not successful at all (e.g., SEI y ETSU, 1996; Palit and Chaurey et al., 2001), that the impact on local development had been overestimated and many financial aspects had been ignored (e.g. IEG, 2008) so that cost recovery reached only 10 to 50%.

Bringing in private investors, both in terms of capital, innovation, and business models, would probably help bridge the existing gap. However, for this to happen, investors need a level playing field, and certainty for their investments. They need the right set of guarantees and incentives. This in turn calls for the development of new dedicated policy framework for the electrification of off-grid rural areas This framework should specify, among other aspects, the areas that are subject to it, the rights and duties of the agents involved, the property rights over the physical infrastructure, the technical restrictions of the service to be provided, and the economic organization of the system which should provide, for private investors, an adequate rate of return for the risk incurred. In addition, this set of policies must be correctly integrated among the existing energy policy of the country.

The policy framework should also ensure the sustainability of these rural electrification installations, something that has been missing in many previous programs. The system should provide a solid basis that guarantees economic sustainability for the installations, that ensures the support from local population, and that accounts for environmental risks.

Unfortunately, as mentioned before, these frameworks are uncommon, both in the literature and in the real world. Bond et al (2007) proposed a policy, but only for solar home systems. Other authors, such as Zerriffi (2007), or Chaurey et al (2012) looked at the viability of different business models. The research closest to ours is that of Schillebeecx et al (2012) who analyzed the institutional, financial, and user requirements for a successful, integrated rural electrification business model.

In this paper we elaborate further on Schillerbeecx et al and others' ideas, to propose a comprehensive but at the same time implementable policy framework for rural electrification in developing countries. The practical orientation of our approach is shown by its application to Guatemala. Indeed, our research was commissioned by the Spanish NGO "Energía Sin Fronteras", following a request by the Guatemalan regulator "Comisión Nacional de la Energía Eléctrica". An earlier and less detailed version of this work was published in Dietrich et al (2011), here we provide more details of the framework proposed and of the practical implementation.

The structure of the paper is the following: after this introduction, section 2 sets the underlying principles for the policy framework proposed, section 3 describes the proposed framework, and section 4 gives some further detail of its application to Guatemala.

## 2. The underlying principles

In order to identify the principles for the policy framework proposed we have used both a top-down and an empirical approach: the top-down one is the identification of the basic principles which should sustain any rural electrification program; the empirical one is the recollection of real, past rural

electrification experiences, both successful and unsuccessful, that can help us determine how to implement in practice these basic principles.

## 2.1 Basic principles

The existing experience in electrification programs in rural off-grid areas has shown that compliance with principles such as universal access to electricity, equitable prices and local participation is crucial for the sustainability of these programs. We list these principles below.

**Universal access to electricity**: Access to modern forms of energy such as electricity fosters sustainable development. Anybody who wants to have access to electricity should have it. The major obstacle in putting this principle into practice is the low paying capacity in rural areas, which is frequently well under the actual cost of electrification. This should not be an impediment to electrify but rather an indicator of the need to use carefully subsidies to pay a part or all of the investment (but not necessarily the cost of operation, maintenance and replacement). Following this principle also means that rather than the electrification cost, other socio-economic factors such as poverty indices or productive activities should be used to classify the priority of electrification areas. (IEA, 2010)

**Equitable prices and reasonable quality:** Electricity access in remote areas without access to the general electricity grid is often related to a lower quality of service. Studies show that electrification programs failed due to lacking knowledge of technology and a refusal of the users who preferred being electrified via the national grid due to higher quality (Duhart, 2001). As a consequence, prices should never be higher in

remote areas than those in grid-connected areas. Again, this principle might lead to the application of subsidies to avoid cost of service being higher than what people can afford.

**Local participation:** The implication of local agents is of vital importance and possible in different levels: The planning and realization of electrification programs should be carried out preferentially by local authorities; Local universities or research centers can find appropriate solutions for technical, economic and social difficulties and involve other local actors in the process. Moreover, the participation of the local community fosters not only the will to be successful in the process of electrifying but also the sustainability during the life of the installations. A correct and responsible use and maintenance should be the task of the users and those who are directly in contact with the installations (Forcano, 2003). E.g. Mapako (2002) concluded that the existence of a structured organization to implement the project, the implication of all actors and a pre-study to determine the most appropriate technology are absolutely necessary. A further interest in encouraging local participation is the promotion of private initiatives that may facilitate local development (Rehman, 2012).

**Promotion of private initiative and competition**: Private initiatives are crucial for rural electrification and for their sustainability in the long-run. To achieve an efficient allocation of resources rules for an equitable and competitive process must be established to ensure transparency (Balachandra, 2011, Chaurey et al., 2012).

## 2.2 Past experiences

In addition, past experience has also identified several challenges to the long-term sustainability of rural electrification policies. The most critical element here is the choice of the business model, which includes not only the funding sources but also the ownership of the installations, the use of subsidies, or the structure of the rates.

Ownership of the installations has been traditionally awarded to the final user (generally using subsidies), as in the case of Bolivia, Brazil, Mexico or others. This final user should therefore care for the maintenance of the installation. Although this maintenance could be subcontracted, the responsibility stayed within the final user. Although this scheme worked well in the beginning, when equipment started to fail users stopped using them and paying the costs. An alternative (e.g. Honduras or Peru) is to opt for a service-based scheme, in which a (private or public) entity supplies electricity, not equipment, and therefore takes care of maintenance. Final users pay a tariff for this, and if they stop paying the installation is taken away.

Another crucial decision is who installs and operates the equipment. The last years have seen an increased need to introduce competition in this area. This competition can take place in three ways: competition for independent projects, competition for a regional market (with exclusive rights, as in a concession), or competition in a market (without exclusive rights). Concessions have become quite popular (e.g. Argentina, Peru, Cape Verde), although they can have some problems when electrified areas already exist, since this model precludes electrification initiatives from other agents.

The selection of the installer/operator can be based on several criteria: the most common ones are the number of connection points for a given subsidy (Chile, several Asian countries) or connection charges. However, these criteria tend to favor larger companies, whereas experiences in Honduras or Panama have shown that local participation from smaller companies greatly enhance the success of the project. Argentina has recently introduced a competitive tender for the required subsidy.

Subsidies also need to be considered carefully. Both the higher costs of rural electrification technologies and equity concerns may make subsidies necessary to electrify some areas. However, deciding on which are the cost elements to be subsidized and also their temporal extension is very relevant. Typically, subsidies for rural electrification have been mostly awarded to initial investments. This may be valid for the extension of the grid, but for off-grid installations this type of subsidy determines the technology to be used, by promoting those with higher investment costs, and also comparing technologies based on their initial expenses rather than on the operation costs.

The cost of electrification in remote areas can be decomposed basically into four components: Cost of investment, operation, maintenance and replacement. While investment costs are fixed costs, especially operation and maintenance and to a wider extent replacement cost depend on the use of the installations and are therefore variable. While the cost of investment occurs at the construction phase of the installations, operation and maintenance are distributed over their whole lifetime. Replacement costs come up when single parts of the installation have a shorter lifetime than the overall installation or if some parts fail earlier. Thus, costs are not spread equally over the lifetime of the installation, depending on the technology chosen. Figure 1 shows the

distribution of these costs for the technologies usually considered for off-grid rural electrification.

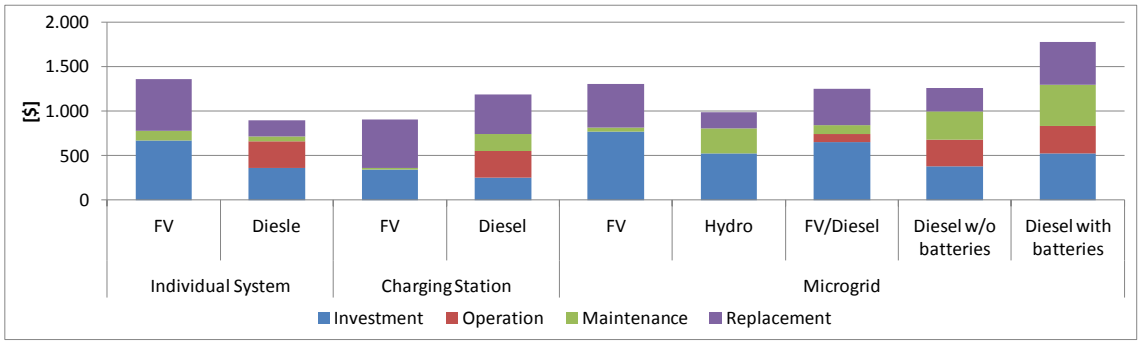


*Figure 1: Cost by origin for different analyzed systems*

As may be seen, for the hydro unit with micro-grid maintenance is around seven times higher than for the photovoltaic micro-grid (14$ versus 2$ per year), but the only replacement cost is the lamps that have to be replaced every six years. The main cost for the micro-grid based on photovoltaic panels is the replacement of batteries every eight years (25% in year eight and fifteen), replacement of lamps in the years seven, thirteen and nineteen (each 12%) and the replacement of inverter, regulator and converter after ten years (8%). Nonetheless, the investment cost of photovoltaic panels are around 774$ and those of hydro units 536$.

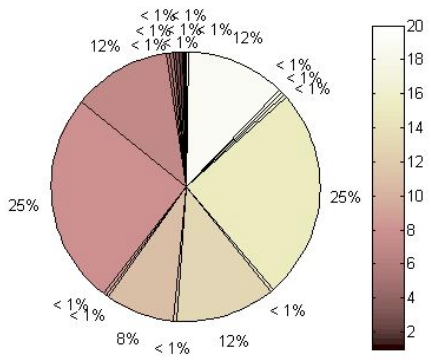


*Figure 2: Annualized cost of microgrid based on PV*

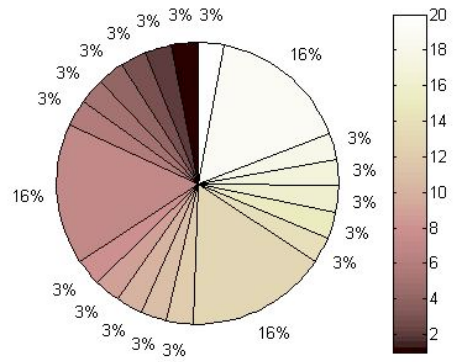


*Figure 3: Annualized cost of hydro microgrid*

Another important aspect is how to certify the allocation of subsidies, that is, how to relate the payment of the subsidy to actual achievements. One of the best practices identified lately has been to pay them based not only on the installation, but also on the commercial and technical quality of the supplier. This may prevent systems failing after some time (and therefore customers not paying), since it incentives suppliers to keep everything in working order. This is also a reason for not paying the subsidy in a single installment, but rather a division of the payment depending on milestones (as in Bangladesh or the Philippines).

Finally, the rate to be paid by the customer also plays a key role in the sustainability of the business model. In many projects, the rate has been so low that it did not even cover the operation and maintenance costs. This is clearly not sustainable. And, on the other hand, the rate has to be adjusted to the capacity to pay of customers or according to equity concerns. Here it is interesting to note that the capacity to pay in off-grid rural areas tends to be

low and seasonal (since income depends mostly from agriculture). But this does not mean that it does not exist: people already spend significant amounts of their income in energy services, in the form of kerosene, batteries or diesel (World Bank, 2008).

# 3. A new policy framework for off-grid rural electrification

As mentioned before, past experiences in off-grid rural electrification have not been successful, mostly because of problems related to the business model and its regulation. Here we propose a new policy framework that, while being faithful to the basic principles outlined before, tries to overcome these problems. We first explain how we translate the basic principles and lessons learned into our regulatory proposal. Then we describe how to put all the regulatory elements together in a framework consistent with the typical administrative structure. Finally, we specify the rights and obligations of the agents involved.

## 3.1Translating the basic principles into the framework

Our proposal first addresses the basic principles for a sustainable rural electrification scheme, and then tries to solve the problems detected in previous frameworks, particularly concerning the access to financial markets and the long-term sustainability of the projects.

### 3.1.1 Universal access to electricity

The framework is intended to serve all off-grid rural communities. It is generally accepted that giving access to all these areas is higher than the capacity to pay. In our application to Guatemala we assessed the cost of electricity supply for a household in 480-830 US$, depending on the technology (this includes investment and O&M costs for the project lifetime, net present value at a 12%

discount rate). However, the capacity to pay is around 480 US$ (measured in the same terms).

Therefore, costs cannot be covered under a free market, which would not result in universal access. Subsidies will be required to cover the difference between actual costs and capacity to pay.

### 3.1.2 Equitable prices and reasonable quality

The goal of the proposed framework is to provide electricity in economic and technical conditions similar to those enjoyed by the areas with access to the grid. However, given that the technical conditions will never be as good as for grid-connected households, the price paid should never be higher than the one paid by grid-connected customers. In the case of Guatemala that means that the price paid should never be higher than 216 US$ (NPV for the lifetime of the project, or 29 US$/year). Again, it can be observed how this results in a need for subsidies, so that the final cost for the consumer does not exceed the price to be paid. On a positive note, the price to be paid is lower than the capacity to pay, which clearly benefits a strong participation.

### 3.1.3 Local participation

Although the proposal does not determine as such the type of investors or developers that should carry out the rural electrification projects, the participation of local entities and communities seems to be critical for the success and long-term sustainability of the projects, both considering the design and implementation. Therefore, the participation of local entities should be incentivized, as well as the active involvement of the affected population in the presentation of electrification proposals, or in the development and management of the projects.

### 3.1.4 Promotion of private initiative and competition

The volume of the investments required for the electrification of off-grid areas is typically very large. For Guatemala, our estimations range between 65 and 110 million US$ (NPV) if we only consider households (not health or education services). Accessing this significant amount of capital is usually one of the most relevant challenges of these projects. This, together with the interest in improving the efficiency of the system, makes it convenient to involve private initiative in the process. Our proposal is that this private participation should be channeled through a competitive tendering system, by which private investors would compete for the subsidies available for the electrification of the different areas identified in an Electrification Plan. These subsidies, which should cover the difference between the costs incurred by the investor, and the revenues paid by the customers, should be released by the entity in charge of the process according to the actual implementation and operation of the installations.

In addition to the translation of the basic principles, the proposal also addresses other topics that are considered important for the success of the projects, based on previous experiences.

### 3.1.5 Property of the installations

We propose to move from an investment-based regime to a service-based one. That is, the electrification is measured in terms of continuity and security of supply during the lifetime of the installation, and not in terms of the equipment installed.

This results in that the property of the installations corresponds to the electricity supplier, and not to the final users. As such, it transfers the

responsibility of maintenance to the supplier, who typically has expert personnel and will therefore maintain better the equipment.

### 3.1.6 Funding

We already mentioned the large need of capital to fund the investments. On the other hand, the lack of revenue makes it necessary to provide subsidies. These subsidies could come from different sources: aid institutions, public budgets, or the general electricity tariff. However, in order to guarantee their availability, and also to decouple investors from funders, we propose the creation of a trust fund that aggregates the different sources of funding, and also keeps them for their sole use in rural electrification projects.

### 3.1.7 The legal framework: requisites for cashing in subsidies, penalties for non-compliance, and tariff setting

In order to guarantee the long-term sustainability of the projects, subsidies should be released progressively, subject to the provision of the service and not to the actual investment. We propose that the initial subsidy should never be larger than 70%, and the rest to be paid during the lifetime of the project, subject to certification and verification procedures regarding the quality and continuity of electricity supply. This however will discriminate against investors with reduced access to external financing.

To ensure this quality and continuity, the winner of the subsidy should sign a contract with the regulating authority in which a compromise is set to supply electricity to any user in the area, under certain quality standards, and which also includes penalties for non-compliance.

Finally, regarding tariffs, our proposal is that the regulatory authority sets the tariffs for rural electrification projects, based on the existing grid tariffs, so that

they are never higher than those. Of course, there may be different tariffs depending on the quality of the supply. On the other hand, the tariff should cover at least the O&M costs.

### 3.1.8 Other elements promoting sustainability

The following elements are introduced to ensure the sustainability of the policy framework, in addition to those described before:

- The temporal scope for the regulation and the financial regime must always go beyond the investment phase
- The costs to be recovered must include not only investment ones, but also replacement, operation and maintenance costs during the lifetime of the installation.
- Local administrations become the monitoring agents for the technical and economic terms of the electricity service, thus involving local communities and decentralizing the administrative process.
- A fraction of the dedicated fund must be devoted to training and education for electricity users.

## 3.2Putting the elements together

We now describe how to combine the regulatory elements described above into an administrative and economic framework consistent with the typical administrative structure in developing countries. Figure 4 shows the general scheme.

### 3.2.1 The administrative framework

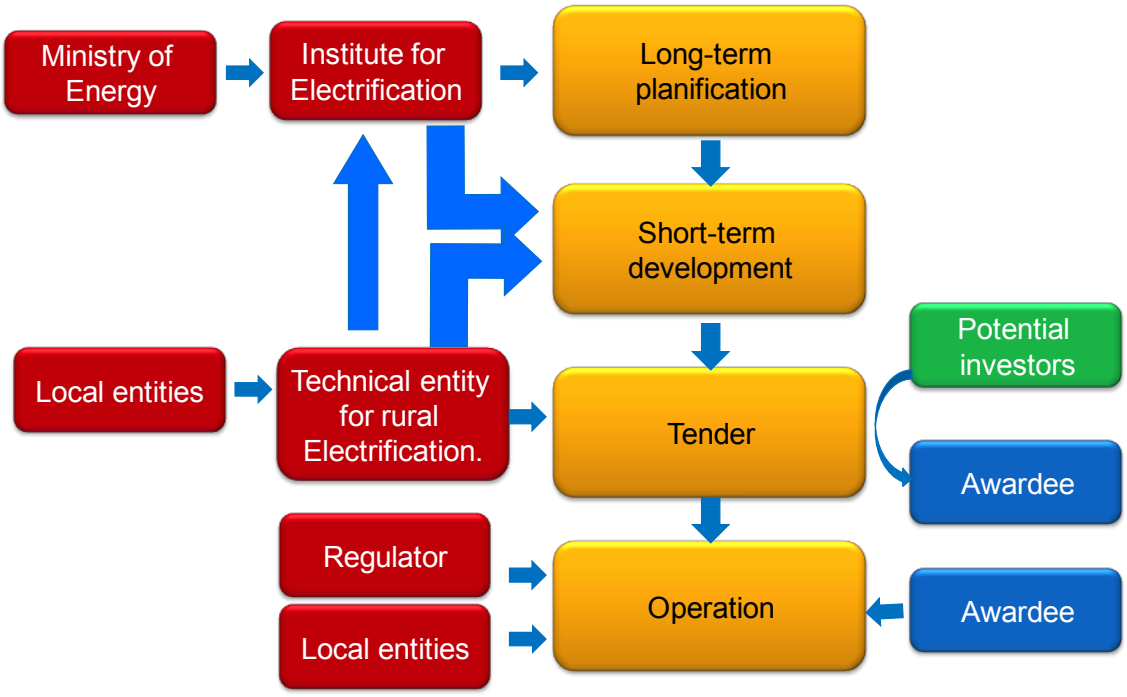


*Figure 4: General administrative framework and procedure*

First, an off-grid rural electrification plan should be promoted by the ministry responsible for energy matters, and prepared by the usual executive branch of the ministry. However, in this case we also propose the creation of a specific entity responsible for the technical aspects of the promotion and implementation of rural off-grid electrification. This entity would also contribute to the plan.

The plan, which should be integrated with a broader electrification plan (for consistency), should determine which are the areas to be considered for off-grid electrification in the long term (15 years, for example), and would also prioritize them based on socioeconomic or electrification indicators. The plan should be updated regularly.

Then, a short term implementation of the plan should also be carried out by the entities proposed. This implementation should decide which are the areas to be electrified in the, say, next 2 years, and what would be the schedule for the tenders to be open for investors. This should be decided based on actual requests by rural communities, on socioeconomic criteria (cost per customer, social returns, etc.), and on the availability of resources (from the trust fund). Figure 5 shows this process.

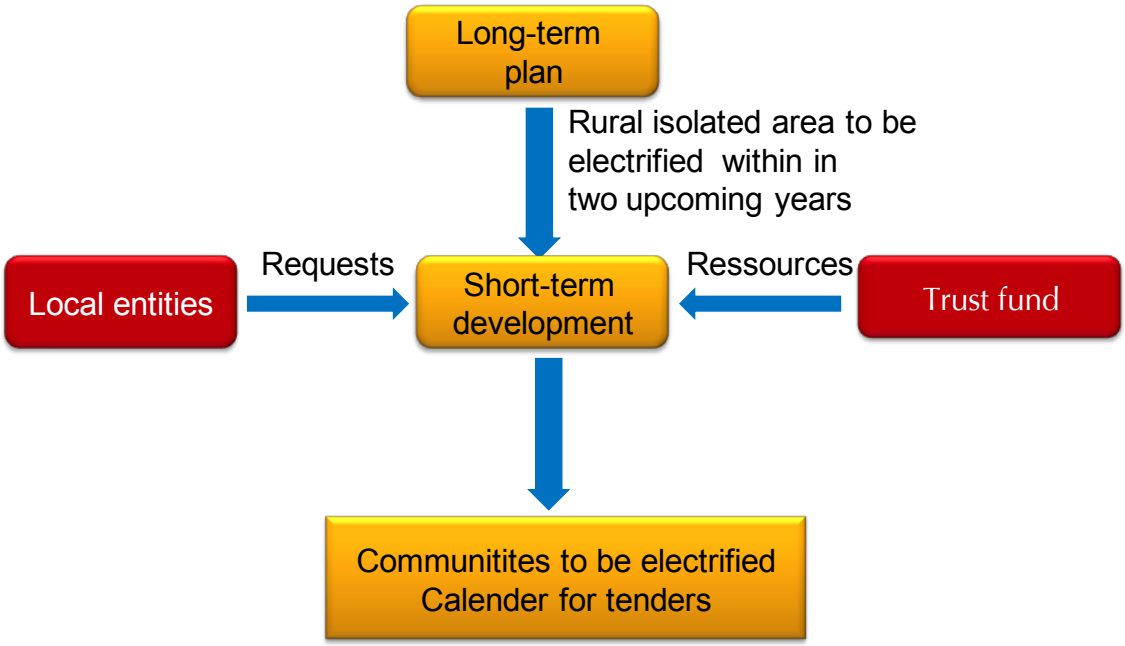


*Figure 5: Short-term development*

Once created the long-term and short-term planning and after having passed the bidding process to determine the highest bidder, the electrification can be put into practice. Apart from the firm that has won the bidding process, three institutions are involved in the operation: the regulator, local authorities and the technical agency that has been created with the objective to aggregate the competences of rural electrification. The operative process is illustrated in Figure 6 below.

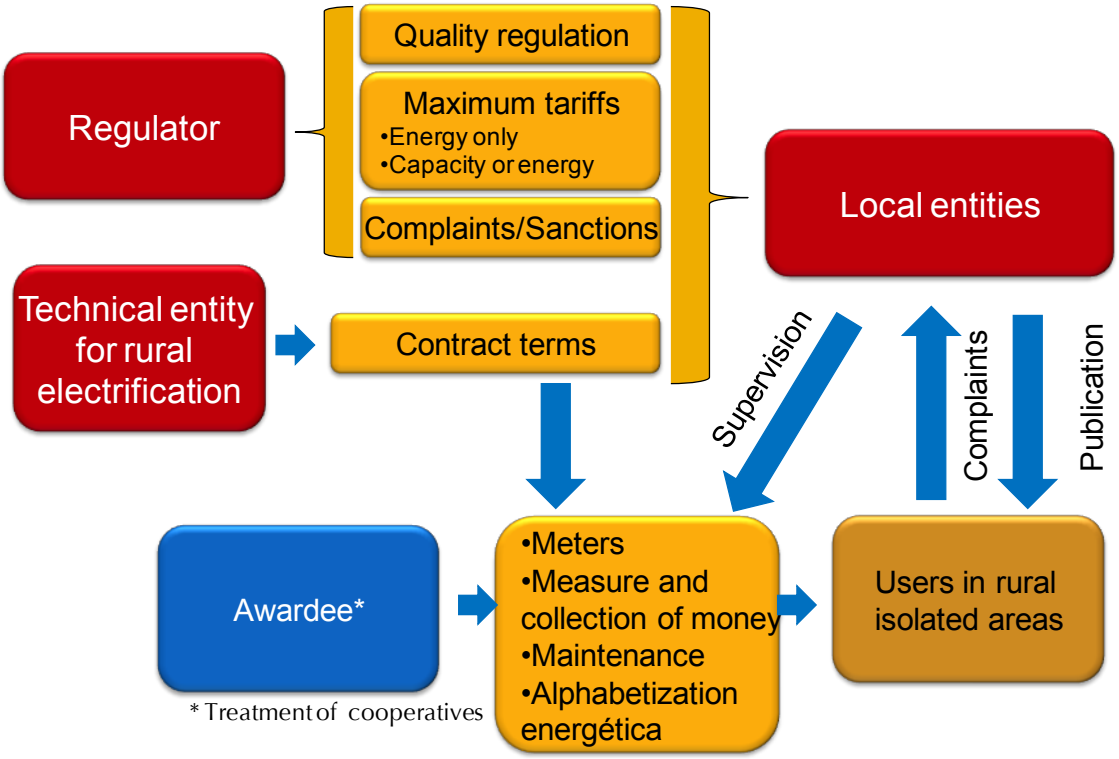


*Figure 6: Operative process*

The regulator will define quality standards, such as voltage levels, maximum hours of interruption of service, maximum time of connection request or security criteria. The operating company is required to comply with these quality standards. In case of noncompliance of technical and commercial quality standards the user may communicate this fact to the local entity and the regulator will be responsible for determining the penalty to be applied.

Furthermore, the regulator will establish maximum tariffs to be applied to the final user. The quantity of the tariff will be directly linked to the quality of the service, capped by the social tariff of grid-connected customers. The tariff will depend either on the installed capacity or the consumed energy. These tariffs will be published and made available to the end user by the local entity. If a

user wants to inform about incorrect tariffs, the local entity will canalize its petition to the regulator.

While the regulator sets quality standards and maximum tariffs, the technical agency will formulate the contract in which the rights and obligations of all implied agents are defined. Moreover, the economic framework and time span of the contract (by default 15 years) will be determined. The local entity may propose other aspects to be part of the contract. The technical agency will be as well the responsible for verifying the progress of electrification.

The operating company will electrify the corresponding area after having signed the contract with the technical agency. It is as well in charge of installing the meters, managing the measurement and collection of the tariff, maintenance and the formation of the users. This is carried out under the supervision of the local entity. As the tariff will not necessarily depend in all areas on the actual energy consumed, meters will only be installed in the areas specified by the regulator. Bills should take into account the seasonality of local productive processes, and this should be part of the contract between winning company and the technical agency.

### 3.2.2 The economic framework

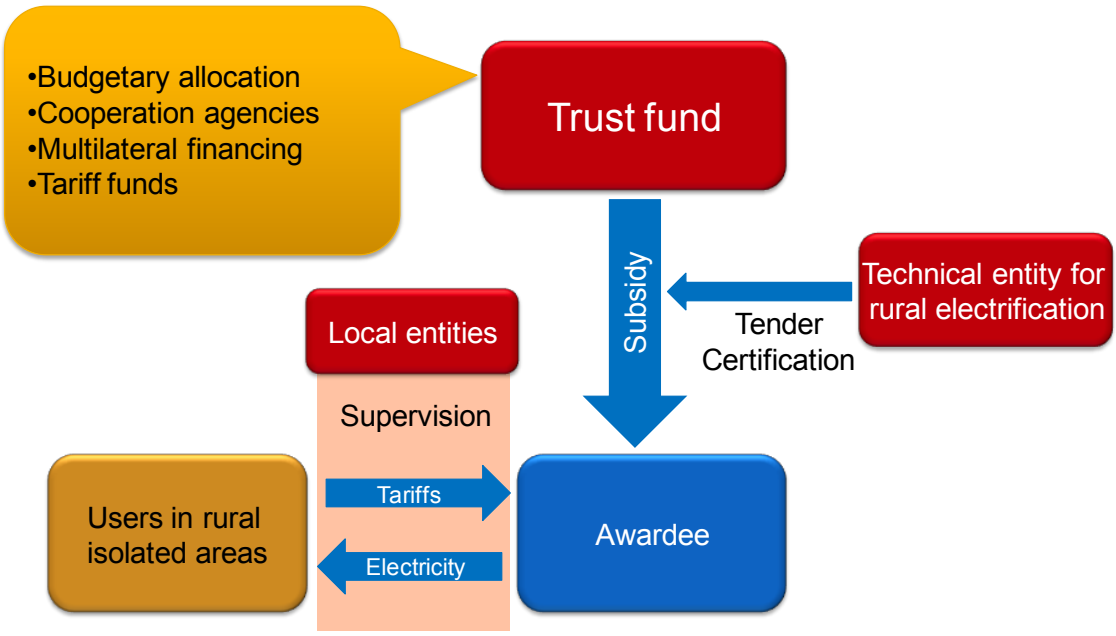


*Figure 7: Economic framework*

In the following paragraph all elements will be discussed separately to facilitate the discussion and possible modification of each of the elements.

- First, we propose the creation of a trust fund, which should be exclusively dedicated to the electrification of rural isolated areas. Budgetary allocations, funds from cooperation agencies, multilateral financing and other tariff funds should be put here. The trust fund should be controlled by a technical entity for rural electrification.

- The Ministry of Energy or the corresponding agency should elaborate an electrification plan for rural isolated areas in which the areas to be electrified and the time horizon for it are identified.

- For each of the considered areas, the Institute for electrification or the corresponding responsible agency should launch a competitive process. In this process the possible investors should present the electrification

projects for the area in question and specify the necessary subsidy, which should be a function of its costs and forecasted income (depending on the established tariff described next).

- The tariffs that can be charged to the users are established by the National Energy Commission as a function of quality of service, and must not be higher than the social tariff for electricity distribution. They can include only a capacity component for installations that do not consume fuel and microgrids. They may include as well an energy component (that requires the use of a meter). The tariff should be published in each community.

- The investor that requires the minimum subsidy (other non-monetary aspects can be considered in the bid, such as the local component of the investing society) is declared awardee for the area. The awardee will sign a contract with the national electrification institute or corresponding entity in which he agrees to provide electricity in that area at a certain quality of service to any user who wishes so during an adequate time frame (in principal equal to the lifetime of the installations).

- Once signed the contract, the awardee can receive the subsidy for each point of connection that he installs (although the installation of the points of connection is not exclusive). The subsidy would come from the trust fund and should be authorized by the technical entity for rural electrification. The payment should be periodical, depending on the used technology and the real incurred costs. In any case the total sum of the subsidy should not be paid all at once at the beginning of the time of

use, but in a gradual way during the whole lifetime of the installations to incentivize the correct operation and maintenance.

- The awardee has the right to receive the tariff directly from the users.
- The local entities act as defenders of the users if it were necessary, in terms of quality of service as well as the tariff payment.

### 3.2.3 Rights and obligations

The users have the right to get electricity at the established quality conditions. Furthermore they have the right to be attended by the company in case of failures, non-availability or missing quality of service. The users have the obligations to pay the established tariff and use the installations in a correct way.

The awardee has the right to perceive the subsidy, to charge the users the tariff and to perceive other incentive payments or income from other programs. He has the obligation of providing electricity to everyone who applies for it, to construct within a determined time the electric facilities and to operate and maintain them. Furthermore he has the obligation to carry out programs of energy alphabetization, maintain the technical and commercial quality standards, read meters when necessary, watch the security of the installations and in general, comply with all the established terms in the proposal in the competitive tender.

# 4. An rural electrification policy for Guatemala

In the year 2008 the project REGEZRA[5] starts with the aim to elaborate a regulation of the electrification of rural isolated areas in Guatemala. This project is launched at request of INDE, the National Institute for electrification of Guatemala. Guatemala's electricity grid reaches around 85% of the whole population. The increase of the electrification rate has been considerable in the last 20 years as in the year 1991 under 50% of the population had access to electricity (INDE, 2012). Increasing this number through the extension of the existing grid seems rather difficult as costs rise fast due to the remote location and low consumption and income of the resting 15% without electricity access. As an alternative isolated systems or micro-grids need to be considered for the electrification of these areas. Normally and as well in the case of Guatemala these types of systems lack a policy framework and thus create uncertainty and prevent small entrepreneurs from investing (Esf, 2008).

Part of the REGEZRA project was the formulation of a basic proposal for this regulation and the economic framework. Calculations have been carried out to determine the most appropriate technology and systems for the electrification process. Financial calculations estimate the amount of funding necessary for the whole electrification process. The willingness to pay of the population and the maximum allowed tariff (the social tariff for grid-connected customers) have also been taken into account to compute the necessary subsidies.

The central objective of the electrification program is to provide access to electricity by private households. Moreover, buildings that are used by the

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[5] Abbreviation in spanish for "Regulación eléctrica de zonas rurales aisladas" which stands for Electric regulation of rural isolated areas.

community such as schools and medical centers were considered for this project. Over 3,700 communities with an average of 37 households each were identified by Universidad Rafael Landívar (2008). It was assumed that every fifth community would dispose of a school and a medical center. The named source together with CIEMAT (2009) and own estimates built the foundation to characterize the electricity demand. The reference case considers a basic demand of 150Wh per day. Scenarios with higher demands have been calculated as well. For the calculations, an exchange rate of 7.5 Quetzales per U.S. dollar has been assumed. A discount rate of 12% is considered including the official interest rate of 7.5% in Guatemala (March 2009) plus a 4.5% risk premium.

Cash flows over twenty years were determined for different technologies for the economic evaluation. They are a result of the difference between income and expenditure. Income is obtained from the sale of electricity at the social tariff set in Guatemala for grid users while costs include operation and maintenance as well as investment costs. Cash flows for individual systems (IS), for battery charging stations (BSC) and for microgrids (MG) for photovoltaics (FV), diesel, hydro and hybrid systems are shown in figure 1. From the cash flow, we determined the amount of subsidy required by each technology. In the case that the electrification program would make use of 25% hydro microgrids, 25% solar home systems, 25% PV microgrids, and 25% battery recharging stations with PV the average cost of the program would be $111 million (net present value over the 20-year lifetime), or $804 per household. This would include also a 20% overhead cost to cover training, dissemination and other administrative costs.

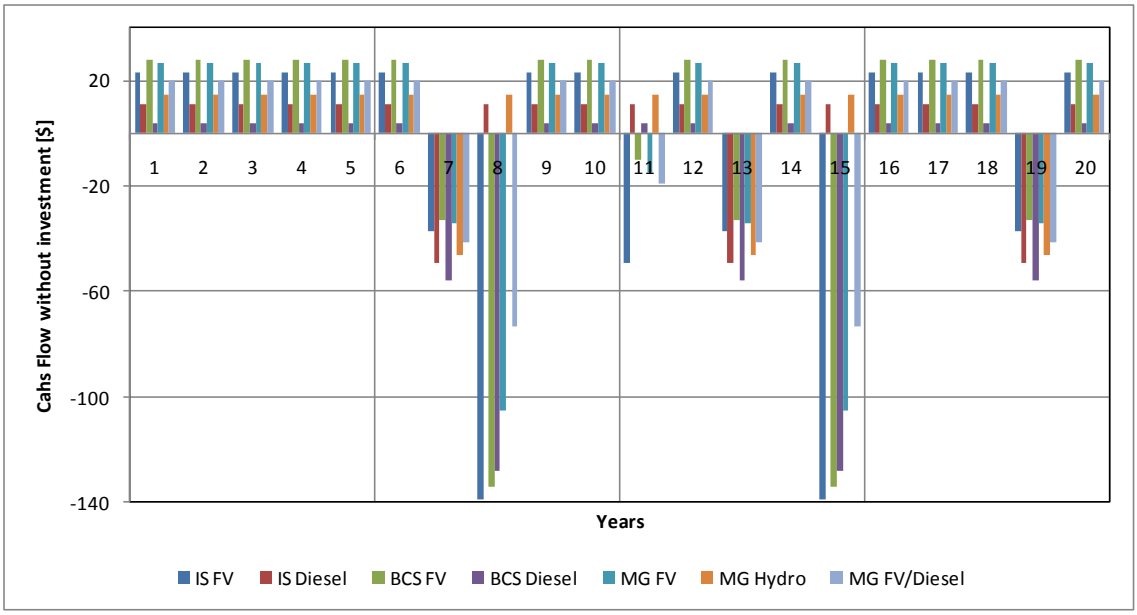


*Figure 8. Different Cash Flows of Individual Systems (IS), Battery Charging Stations (BCS) and Microgrids (MS)*

Taking into account the current social tariff for electricity we obtain an income of $30 million, or $216 per household in net present value terms for the electrification program. As proposed in the economic model, in each area a competitive bidding process determines the minimum subsidy per connection point. To determine the level of subsidies we assumed that the internal rate of return of the investment would equal the rate of discount for the Net Present Value (12%). Therefore, a subsidy that leads to a NPV of zero would be enough to make the facilities viable. We assumed that no additional funding would be needed and all operating margins are covered. As a result, $79 million, or $572 per household of subsidies are required. However, depending on the technology this system would lead to punctually very high expenses for the supplier for example at the beginning for the investment. This aspect as well as the low incentive for the right operation of the facilities in the case that the whole subsidy is paid at the beginning of the lifetime of the installations, a gradual distribution of the subsidy is considered. 70% of the whole subsidy for

investment will be paid to the supplier at the beginning, and the remaining money will be transferred in the years 5, 10 and 15 of the lifetime. That means that 10% of the subsidy will be paid in each of the mentioned years. This leads naturally to the fact that the supplier needs to have a high borrowing capacity and smaller suppliers might be discriminated. Therefore, this aspect needs careful consideration. An electrification program to be carried out in ten years would need the financing as shown in the table, taken from the dedicated fund.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Yearly expenses | 4 | 4 | 4 | 4 | 4 | 6 | 6 | 7 | 8 | 8 |

*Yearly expenses from the dedicated fund (in million US$)*

Apart from the four years where the subsidy for the investment is received, subsidies will also be paid in years where parts of the facility have to be replaced.

The remaining subsidy amounts to be $138 million ($61 million in NPV terms), which is estimated to be within an affordable range for a country like Guatemala.

## 5. Conclusions and future policy developments

There is a pressing need for additional investment in rural electrification, in order to give access to electricity to the more than 1.5 billion people without it. And this additional investment will only come from private sources, which in turn need a predictable, stable, sustainable and orthodox policy framework. In this paper we have proposed such a framework, and have demonstrated its practical applicability to a country like Guatemala.

Our framework combines an understanding of the basic principles that should underlie every rural electrification program, with a careful consideration of elements that guarantee the economic and technical sustainability of the projects, such as the focus on service rather than on investment, the design of the tariffs, the involvement of local participation, or the detailed definition of the financial and administrative processes required.

We also show the applicability of the framework proposed to Guatemala, and we estimate the financial implications of a comprehensive program. Thus, we have determined that the tariff to be paid by consumers should be around 220 US$, while the cost per household of the electrification program would range from 500 to 800 US$. That means that a subsidy will be required, amounting to $79 million for 20 years. In the paper we propose an administrative structure for managing the subsidies.

We believe that this policy framework may contribute to facilitating private investment in rural electrification, by creating a level playing field for investors, who can in turn develop innovative business models, converting this huge challenge into an interesting business opportunity, as proposed e.g. in IFC (2012).

As mentioned earlier, this framework is currently being evaluated in Guatemala, where the energy authorities have already expressed their interest in using it, and pilot projects have already started in remote, rural areas. However, although these projects are showing the potential benefits of our approach, they are also showing that real-life implementations may encounter additional problems that need to be addressed, even when the investment is already available, such as developing the trust of the population to engage them in

these models, or overcoming cultural, language or educational barriers. More work is clearly needed, and is currently under way in these areas.

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